SYSTEM AND METHOD OF IDENTIFYING SOURCES FOR BIOLOGICAL RHYTHMS

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 61/569,132 filed on Dec. 9, 2011, the disclosure of which is incorporated herein by reference in its entirety.

FEDERAL GRANT

This invention was made with government support under Grants HL070529 and HL083359 awarded by the National Institutes of Health. The government has certain rights in the invention.

BACKGROUND

1. Field

The present application relates generally to biological rhythm disorders. More specifically, the present application is directed to a system and method of identifying a source (or sources) of a biological rhythm disorder, such as a heart rhythm disorder.

2. Brief Discussion of Related Art

Heart rhythm disorders are common and represent significant causes of morbidity and death throughout the world. Malfunction of the electrical system in the heart represents a proximate cause of heart rhythm disorders. Heart rhythm disorders exist in many forms, of which the most complex and difficult to treat are atrial fibrillation (AF), ventricular tachycardia (VT) and ventricular fibrillation (VF). Other rhythm disorders are more simple to treat, but may also be clinically significant including atrial tachycardia (AT), supraventricular tachycardia (SVT), atrial flutter (AFL), premature atrial complexes/beats (SVE) and premature ventricular complexes/beats (PVC). While under normal conditions the sinus node keeps the heart in sinus rhythm, under certain conditions rapid activation of the normal sinus node can cause inappropriate sinus tachycardia or sinus node reentry, both of which also represent heart rhythm disorders.

Treatment of heart rhythm disorders—particularly complex rhythm disorders of AF, VF and VT—can be very difficult. Pharmacologic therapy for complex rhythm disorder is not optimal. Ablation has been used increasingly in connection with heart rhythm disorders by maneuvering a sensor/probe to the heart through the blood vessels, or directly at surgery, and delivering energy to a location of the heart to mitigate and in some cases to eliminate the heart rhythm disorder. However, in complex rhythm disorders ablation is often difficult and ineffectual because tools that identify and locate a cause (source) of the heart rhythm disorder are poor and hinder attempts to deliver energy to a correct region of the heart to eliminate the disorder.

Certain systems and methods are known for treating simple heart rhythm disorders. In a simple heart rhythm disorder (e.g., atrial tachycardia), the source of the disorder can be identified by tracing activation back to the earliest location, which can be ablated to mitigate and in some cases to eliminate the disorder. However, even in simple heart rhythm disorders, ablating the cause of a heart rhythm disorder is challenging and experienced practitioners often require hours to ablate simple rhythm disorders that show consistent beat-to-beat activation patterns, such as atrial tachycardia.

There are few, if any, known systems and methods that have been successful with respect to identifying the sources or causes for complex rhythm disorders such as AF, VF or polymorphic VT. In a complex rhythm disorder, an earliest location of activation onsets cannot be identified because activation onset patterns change from beat to beat and are often continuous without an earliest or a latest point.

Diagnosing and treating heart rhythm disorders generally involves the introduction of a catheter having a plurality of sensors/probes into the heart through blood vessels of a patient. The sensors detect electric activity of the heart at sensor locations in the heart. The electric activity is generally processed into electrogram signals that represent the activation of the heart at the sensor locations.

In a simple heart rhythm disorder, the signal at each sensor location is generally consistent from beat to beat, enabling identification of the earliest activation. However, in a complex rhythm disorder, the signal at each sensor location from beat to beat may transition between one, several, and multiple deflections of various shapes. For instance, when a signal for a sensor location in AF includes 5, 7, 11 or more deflections, it is difficult if not impossible to identify which deflections in the signal are local to the sensor location in the heart (i.e., local activation onset) versus a nearby sensor location in the heart (i.e., far-field activation onset) or simply noise from another part of the patient's heart, other anatomic structures or external electronic systems. The foregoing deflections make it difficult if not impossible to identify activation onset times of the beats in a signal at a sensor location.

Current strategies in complex rhythm disorders have also considered regularity in signals at sensor locations as a surrogate for the source of the complex rhythm disorder, i.e., the source being more organized at certain sensor locations than at adjacent sensor locations. For example, U.S. Pat. No. 7,117,030 by Berenfeld et al. and U.S. Pat. No. 5,792,189 by Gray et al. exemplify the current approaches in which the source(s) for variable atrial fibrillation (AF) are considered highly regular. However, these approaches have indeed been disappointing in finding the source to treat human atrial fibrillation. As another example, Sanders et al. (Circulation 2005) found that locations of regularity, indicated by high spectral dominant frequency with a high regularity index, were rarely locations where AF terminated by ablation in complex (persistent) AF. Other studies such as Sahadevan (Circulation 2004) identified locations of rapid regular activity in human AF that have never been shown to drive human AF. Animal models (Kalifa, Circulation 2006) and human studies (Nademanee, J Am Coll 2004) suggest that complex fractionated atrial electrograms (CFAE) may form at the junction from regular 'drivers' to variable AF. In clinical use, however, such CFAE sites are poor targets for AF treatment (Oral, Circulation 2007).

There are no known systems and methods that have been able to identify the source (or sources) for a heart rhythm disorder independently of identifying and assigning activation onset times to signals of successive beats. Given the difficulties in identifying the activation onset times, this has significantly limited diagnosis of the source (or sources) of heart rhythm disorders, especially for complex rhythm disorders, and has limited treatment attempts at their elimination.

SUMMARY

The present invention is applicable to identifying sources of various rhythms, including normal and disordered heart rhythms, as well as other biological rhythms and rhythm disorders, such as neurological seizures, esophageal spasms,